2-D Super Resolution Used on Mars Pathfinder

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The Data Understanding Group at Ames Research Center is developing the theory and practice of combining information from multiple images. The group has already produced a technique called Two-Dimensional (2-D) Super-Resolution; this technique uses multiple images of the same scene, taken by the same instrument under nearly identical lighting conditions and from nearly identical instrument orientations, and produces a single output image of higher resolution than the input images. The inescapable slight differences in instrument orientation, and in the registration of scene features on the pixel grid of the instrument, ensure that any point in the scene is pixelized differently in each input image. The 2-D Super-Resolution technique exploits these registration differences to create a mathematical model of the original scene—using the information from all the low-resolution input images—which has much higher resolution than those images. The resolution can typically be improved by a factor equal to the square root of the number of input images. This model can then be used to generate a high-resolution output image.

Until 1997, the 2-D Super-Resolution technique had been used only for "data mining." Dramatic improvements had been demonstrated by chance on some identical Viking Orbiter images, and some modest but scientifically used results had been obtained on potential landing sites.

During the Mars Pathfinder mission (July through October 1997), the technique was used by Ames personnel working on the Pathfinder science team. The Imaging for Mars Pathfinder (IMP) camera on the lander was commanded to take image sequences especially designed to be processed by the super-resolution algorithm.

The science team was pleased with the results, and made super-resolution sequences one of the routinely commanded sequences for the rest of the primary mission and into the extended mission. It was to be run at low priority until the final multi-spectral panorama was complete, and then at high priority. This would have resulted in a flood of data if the spacecraft had survived a few weeks longer and completed the panorama, and automatic processing was put in place to prepare for this. As it is, over a dozen rocks and horizon features were still super-resolved, including both Twin Peaks, Big Crater, Wedge, Half Dome, Stack, and the Flotilla of Flat Tops.

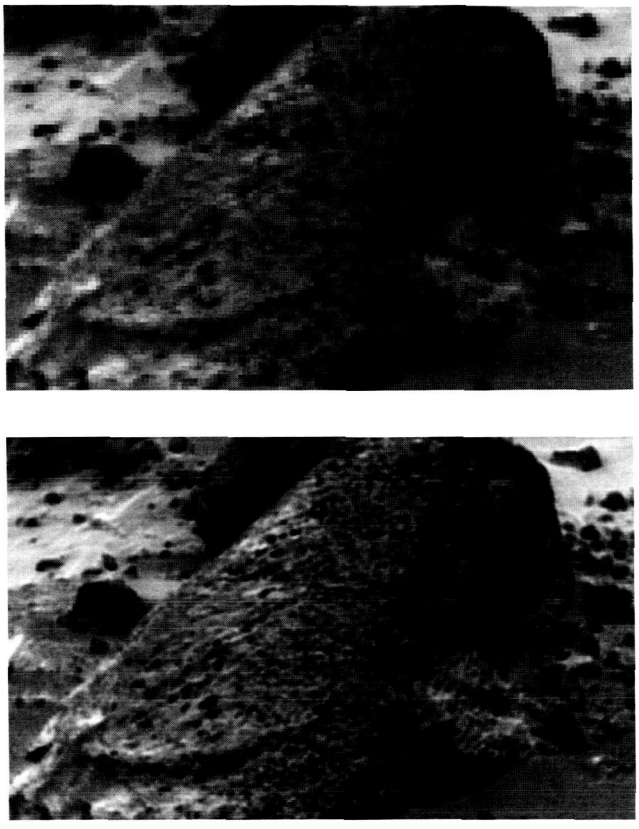

Fig. 1. The top image of Wedge, a rock a few meters to the south of Pathfinder, is one of the 25 images taken on Sol 20 (July 23). The super-resolved image (bottom) was created from the 25 images to demonstrate the 2-D super-resolution technique. It shows the pitted texture for the first time. This was later confirmed when Sojourner rover took closeups of Wedge on Sol 35.

Some early near-field targets were selected, in part, to validate the super-resolution algorithm and

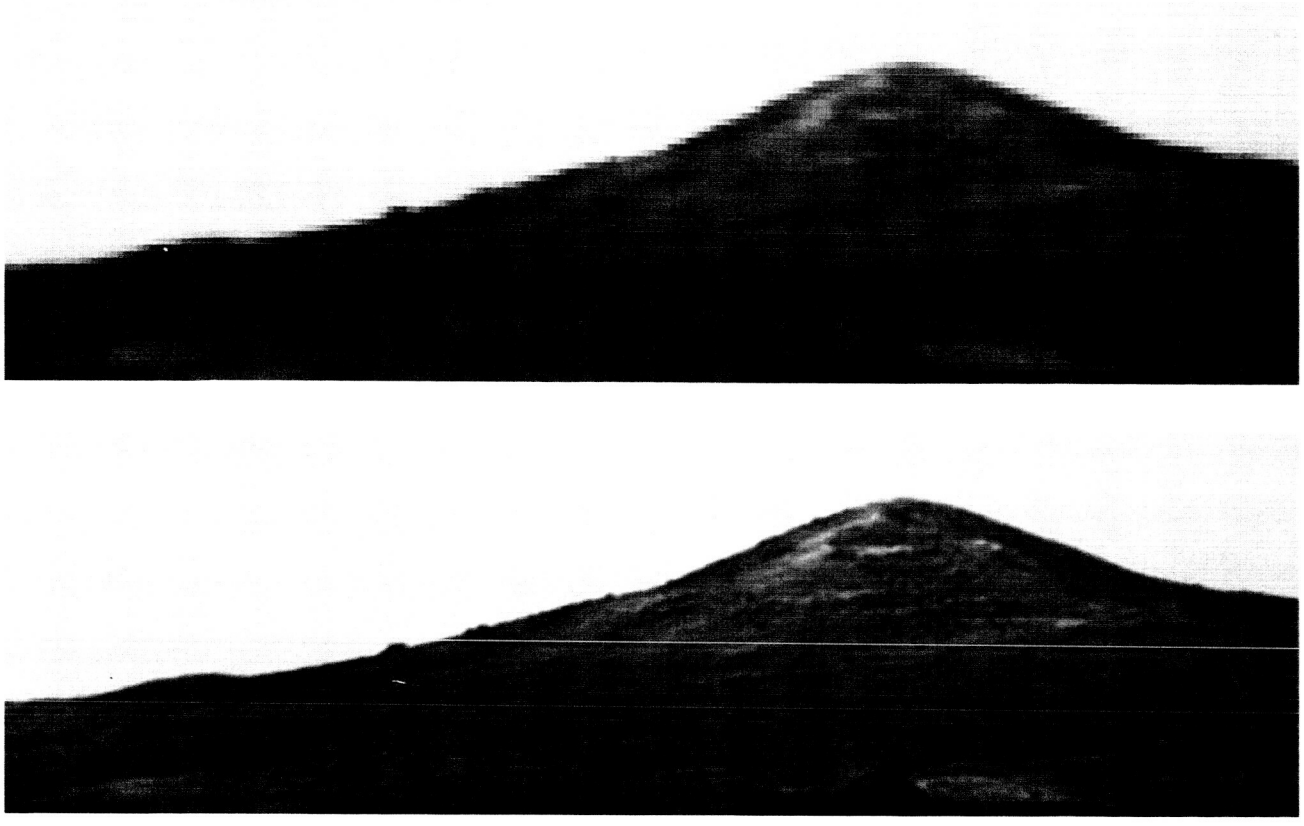

Fig. 2. One (top) of the forty-two images of South Peak—one of the famous Twin Peaks to the west of the Pathfinder landing site—that were processed to create a super-resolved image. The result (bottom) is about five or six times sharper than the input images. This is the sharpest picture of South Peak available anywhere. Note possible outcropping in the foreground.

show that its results could be trusted. The super-resolution algorithm was able to show the pits in the rock named Wedge (see first figure), which no human had ever seen up until that point. In all the raw IMP images, the texture of Wedge was too fuzzy to discern; the science team could not agree whether the rock was bumpy, like granite, or pitted, as a volcanic rock with vesicles might be. This observation was confirmed two weeks later when Sojourner approached Wedge for the first time and took closeups. (This took place just before the rover's entirely too-close encounter, when it was wedged on top of Wedge for more than two days!)

The super-resolved images of the Twin Peaks indicate that the horizontal features, just barely visible in the raw images, probably consist of lines of boulders, rather than layered deposits, and that South Peak is not so different from its twin as it first appeared (second figure). The South Peak image also happens to capture a rock in the foreground, which shows evidence of layering in the super-resolved image. This could be an outcropping, a tempting target for a rover, although it was far beyond Sojourner's range.

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